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The cost-effectiveness of patient-controlled analgesia vs. standard care in patients presenting to the emergency department in pain, who are subsequently admitted to hospital

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Summary

The clinical effectiveness of patient-controlled analgesia has been demonstrated in a variety of settings. However, patient-controlled analgesia is rarely utilised in the emergency department. The aim of this study was to compare the cost-effectiveness of patient-controlled analgesia vs. standard care in participants admitted to hospital from the emergency department with pain due to traumatic injury or non-traumatic abdominal pain. Pain scores were measured hourly for 12 h using a visual analogue scale. Cost-effectiveness was measured as the additional cost per hour in moderate to severe pain avoided by using patient-controlled analgesia rather than standard care (the incremental cost-effectiveness ratio). Sampling variation was estimated using bootstrap methods and the effects of parameter uncertainty explored in a sensitivity analysis. The cost per hour in moderate or severe pain averted was estimated as £24.77 (€29.05, US\$30.80) (bootstrap estimated 95%CI £8.72 to £89.17) for participants suffering pain from traumatic injuries and £15.17 (€17.79, US\$18.86) (bootstrap estimate 95%CI £9.03 to £46.00) for participants with non-traumatic abdominal pain. Overall costs were higher with patient-controlled analgesia than standard care in both groups: pain from traumatic injuries incurred an additional £18.58 (€21.79 US\$23.10) (95%CI £15.81 to £21.35) per 12 h; and non-traumatic abdominal pain an additional £20.18 (€23.67 US\$25.09) (95%CI £19.45 to £20.84) per 12 h.

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Introduction

Patient-controlled analgesia (PCA) using intravenous (i.v.) opioids has been a standard of care for many patients following surgery for over 20 years [1, 2]. However, in some clinical settings such as the emergency department, PCA has not been routinely adopted into clinical practice. The few trials which have tested the use of PCA in this setting have shown that it is as effective as nurse-titrated analgesia. However, almost all the studies were limited to the initial 4 h of care [3, 4]. The clinical effectiveness of PCA in the emergency department has been confirmed, but in order for this analgesic modality to be widely adopted, evidence for cost-effectiveness is also required [3]. The cost-effectiveness of PCA for postoperative pain relief was extensively investigated in the 1990s and the drivers of the marginal costs were identified as the cost of equipment, analgesic drugs, and staff time. As the use of PCA has become routine practice in many circumstances, there have been fewer new studies, and none in the emergency department setting. [5]

This paper describes the results of an economic evaluation that was part of the PAIN SoluTions In the Emergency Setting (PASTIES) trial [6]. In summary, PASTIES comprised two parallel multicentre open label, randomised trials of PCA vs. standard care that were statistically powered separately, but run side-by-side using a shared protocol. Pain scores were recorded hourly for the first 12 h, and the total pain experienced was calculated as the area under the curve.

The aim of this economic study was to evaluate the cost per hour required to avoid moderate to severe pain using a PCA from a National Health Service (NHS) cost perspective.

Methods

Full details of the protocol for the PASTIES trials have been published previously [6]. In brief, the patient populations were adult patients attending the emergency department with pain from either traumatic injuries or non-traumatic abdominal pain, who were admitted to an in-patient ward. Patients with chronic pain or a history of significant opioid use were not studied. Participants recorded a pain score at hourly intervals over 12 h following their recruitment to the study. Pain scores were recorded using a visual analogue scale in the form of a 100-mm line anchored with 'no pain' at one end and 'worst pain possible' at the other end. Pain scores were recorded as the distance in millimetres from the 'no pain' end of the scale. Moderate to severe pain was defined by a pain score ≥ 45 mm [7]. Participants also recorded periods of sleep retrospectively and, for the purposes of the main economic evaluation, these have been regarded as occasions when they were not in moderate to severe pain.

The study samples for this economic evaluation were drawn from participants recruited to the PASTIES study ($n = 196$ with abdominal pain and $n = 200$ with pain related to traumatic injury). An opportunistic sample of 20 participants (10 in the PCA group and 10 in the standard care group) was used for the observational time and motion study, equally

divided between those with pain due to trauma and abdominal pain. Participants were observed over the 12 h of the economic study and the time health-care staff engaged in pain management activities was recorded. The marginal costs of PCA in participants with traumatic injuries and those with non-traumatic abdominal pain were assessed separately.

Patient-controlled analgesia equipment costs have been estimated based on the NHS purchase price of the Graseby 3300 PCA device (Smiths Medical Inter-national Ltd., Hythe, UK) assuming a 5-year useful life. For the main analysis, the per participant equipment cost has been estimated on the basis that the PCA equipment is not available for other use for 24 h, and includes the costs of drugs (morphine sulphate 1 mg.ml⁻¹ solution for injection), portage, disposables, cleaning, servicing and maintenance costs. Pump maintenance costs during use have been treated as staff activity and valued as staff time. Estimates of the costs of staff time were derived from an observational study of the various activities entailed in pain management in the emergency department and ward. The timings for the various activities were similar to those reported in a large time and motion study, with the exception of the time taken to instruct participants in the use of the PCA equipment [8]. Due to the possibility that the observation conflated PASTIES study instructions with PCA use, a separate study of PCA instruction in routine care in the post-anaesthetic care unit was used to estimate timings for this aspect of staff time. Variation in the costs of the individual tasks reflects both variation in the time taken and range of professions and grades of staff who undertook them. The staff costs for categories of analgesic-related activities were estimated by sampling the distributions found in the observational study. Drug use for study participants was captured from their medical records and was costed as NHS prices from the British National Formulary [9]. Cost-effectiveness is reported as the additional cost per hour in moderate to severe pain avoided by using PCA rather than standard care, namely the incremental cost-effectiveness ratio. Sampling variation was estimated using bootstrap methods and the effects of parameter uncertainty explored in sensitivity analysis.

Results

Costs were significantly greater in the PCA arm of both trials: traumatic pain additional cost £18.58 (95% CI £15.81 to £21.35) (£21.79 US\$23.10); and non-traumatic abdominal pain additional cost £20.18 (95%CI £19.45 to £20.84) (£23.67 US\$25.09). In the traumatic pain trial, PCA participants spent, on average, less time in moderate or severe pain (36.2% vs. 44.1%; mean difference (CI) 7.8 (1.0 to 16.5)%), but the difference was not statistically significant ($p = 0.081$) [10]. In the abdominal pain trial, PCA participants spent significantly less of the study period in moderate or severe pain (32.6% vs. 46.9%; mean difference (CI) 14.5 (5.6–23.5)%, $p = 0.002$) [11].

The mean (SD) costs of analgesic and anti-emetic drugs used in the traumatic pain trial were £8.44 (12.15) (£9.90 US\$10.49) in the PCA group and £5.32 (6.79) (£6.24 US\$6.61) in the standard care group. For the abdominal pain trial, the mean (SD) drug costs were £7.79 (1.95) (£7.79 US\$9.69) in the PCA group and £3.28 (2.24) (£3.85 US\$4.08) in the standard care group.

The results of the observational study are summarised in Table 1. This shows the timings for categories of analgesic-related staff activities together with the associated employment. Overall, the average staff costs (SD) in the traumatic pain trial were estimated as £8.42 (0.82) (€9.87 US\$10.47) for the PCA group and £6.70 (0.99) (€7.86 US\$8.33) for the standard care group.

Table 1 Time and staff costs for patient-controlled analgesia and standard care groups per participant during the 12-h study period. Values are mean (SD).

PCA group	Time; min	Cost; £
Drug chart	2.5 (1.3)	0.8 (0.4)
Set up	13.4 (4.2)	3.3 (1.2)
PCA instruction	7.0 (4.3)	2.0 (1.1)
Pain scoring	3.8 (1.3)	1.0 (0.3)
Further analgesia	7.2 (12.7)	1.7 (3.2)
PCA maintenance	3.0 (15.5)	0.8 (1.0)
Nausea management	0.7 (3.3)	0.2 (0.6)
Additional vital signs measurement	0.5 (1.2)	0.1 (0.3)
Standard care group		
Drug chart	3.5 (1.6)	1.7 (1.1)
Administration of analgesia	7.8 (9.6)	5.0 (5.2)
Reassessment of pain	5.0 (2.6)	1.2 (0.6)
Further analgesia	7.4 (2.0)	2.0 (1.5)
i.v. line	1.3 (2.5)	0.3 (0.6)

PCA, patient-controlled analgesia; i.v., intravenous.

In the abdominal pain trial the estimates of the average staff costs (SD) were £8.30 (0.84) (€9.73 US \$10.32) for PCA participants and £6.64 (1.10) (€7.79 US\$8.26) for the standard care group.

The annual costs of the PCA equipment were £1265 (€1484 US\$1573) comprising depreciation, electrical testing, calibration and rebuild costs, allowing for 2 days down-time for servicing. The annual costs equate to £3.49 (€4.09 US\$4.34) per day. The per-use costs, comprising drugs, disposables, portorage, cleaning and maintenance amounted to £11.02 (€12.92 US \$13.70), making the total cost used in the primary analysis £14.51 (€17.02 US\$18.04).

The results of the economic evaluation of the traumatic pain trial are summarised in Table 2. The cost per hour in moderate or severe pain averted (incremental cost effectiveness ratio) was estimated as £24.77 (€29.05, US\$30.80) (bootstrap estimated 95%CI £8.72 to £89.17). The results of the economic evaluation of the abdominal pain trial are summarised in Table 3. The incremental cost-effectiveness ratio for participants

with abdominal pain was estimated as £15.17 (€17.79, US\$18.86) (bootstrap estimated 95%CI £9.03 to £46.00).

Table 2 Economic evaluation of traumatic pain trial. Values are mean (SD).

	PCA group n = 99	Standard care group n = 101
Staff costs; £	7.63(0.79)	6.68 (1.35)
Drug costs; £	8.44(12.14)	5.32 (6.79)
Patient-controlled analgesic device cost; £	14.51	-
Total costs	30.58(12.14)	12.00 (7.10)
Time in moderate or severe pain; h	3.95(3.64)	4.70 (3.58)

PCA, patient-controlled analgesia.

Table 3 Economic evaluation of abdominal pain trial. Values are mean (SD).

	PCA group n = 99	Standard care group n = 101
Staff costs; £	7.64 (0.97)	6.48 (1.34)
Drug costs; £	7.79 (1.95)	3.28 (2.24)
Patient-controlled analgesic device cost; £	14.5 1	
Total costs	29.9 4 (2.19)	9.76 (2.47)
Time in moderate or severe pain; h	3.95 (4.13)	5.28 (3.70)

PCA, patient-controlled analgesia.

The sampling variation associated with the estimate of the incremental cost effectiveness ratio in the traumatic pain trial is illustrated in Fig. 1, which shows the distribution of marginal costs and effects found in 1000 bootstraps of the trial data.

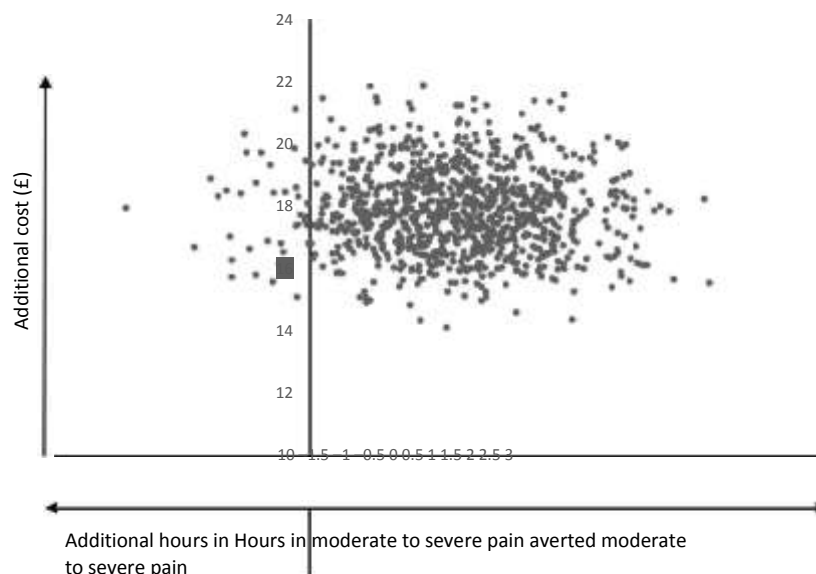


Figure 1 Sampling variation for traumatic pain trial: incremental cost-effectiveness ratio estimates from 1000 bootstrap samples shown on the cost-effectiveness plane.

The variation in the estimated marginal costs is relatively small, ranging from £14.11 to £21.87 (€16.55 to €25.65 US\$17.54 to US\$27.19), while the estimates for additional hours in moderate or severe pain range from 1.07 h to 2.33 h for standard care groups. The cost-effectiveness accept-ability curve illustrates effects of the sampling uncertainty in terms of how likely it is that the use of PCA will prove effective given a specified willingness to pay to avert an hour in moderate to severe pain. For example, if a decision taker were willing to pay £40 (€47 US \$50) to avert an hour in moderate to severe pain, the probability of achieving that hour for that cost would be 0.829 (Fig. 2). For abdominal pain, the estimates of the marginal costs of PCA lie between £18.86 and £21.47 (€22.12 to €25.18 US\$23.45 to US\$26.70), and estimates for hours in pain between 0.68 additional hours in pain to 3.39 fewer hours in pain (Fig. 3). At a willingness to pay cost of £40 (€47 US\$50) the probability of realising the aim of averting an hour in moderate to severe pain would be 0.932 (Fig. 4).

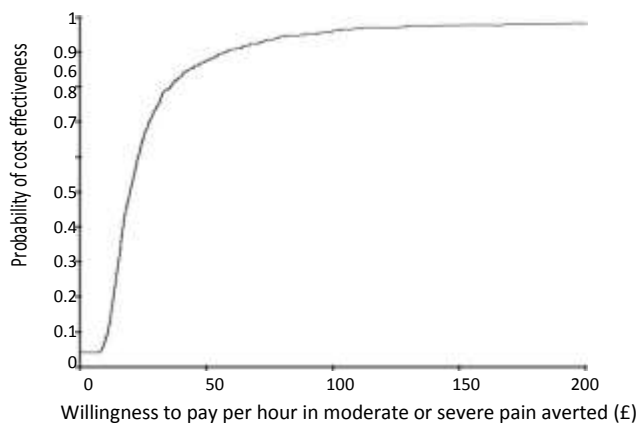


Figure 2 Cost-effectiveness acceptability curve, traumatic pain trial.

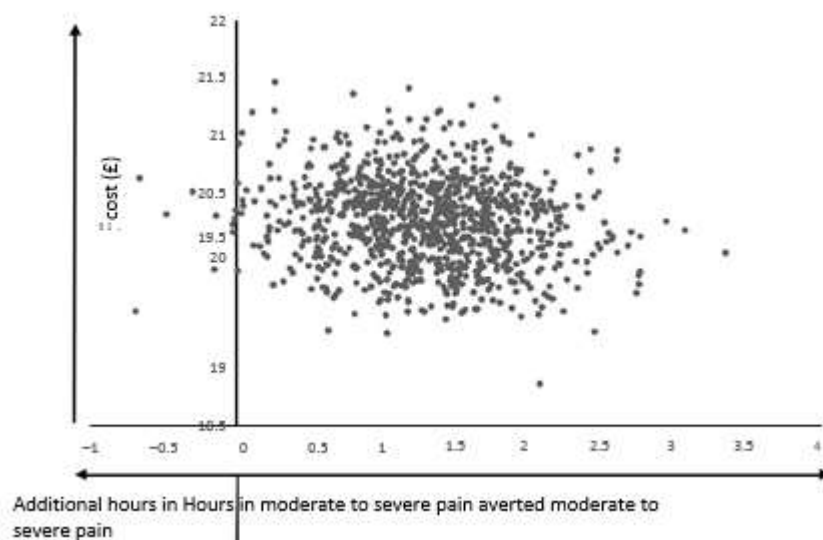


Figure 3 Sampling variation for abdominal pain trial: incremental cost-effectiveness ratio estimates from 1000 boot strap samples shown on the cost-effectiveness plane

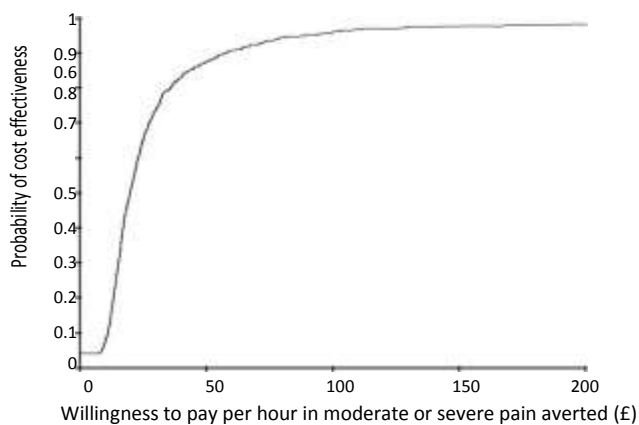


Figure 4 Cost-effectiveness acceptability curve, abdominal pain trial.

There was considerable variation in the numbers of hourly pain observations for participants in the two trials, for the most part because of the different amounts of time participants spent asleep. The primary economic analysis did not take account of differences in the 'time at risk' on the grounds that the currency for the evaluation was hours in pain. However, although differences in the average numbers of observations between PCA and standard care groups were relatively small, it is possible that they may affect the estimate of marginal differences in hours in pain and hence the estimate of the incremental cost effectiveness ratio. To gauge the extent of any such effect, for each individual the proportion of waking hours in pain was multiplied by the mean number of hours observed in the trial. For the traumatic pain trial the mean hours observed was 8.31, so for this analysis the proportion of each individual's waking hours in pain were multiplied by 8.31 to give a 'standardised' measure of hours in pain. On this basis, the additional cost per hour in pain averted was £31.50 (€36.94 US \$39.17) (bootstrap estimate 95%CI £14.29 to £88.71). This estimate is higher than that from the main analysis, reflecting a reduced estimate of marginal effectiveness of PCA. For the abdominal pain trial the average hours observed was 9.10. On this basis, the estimate of the additional cost per hour in pain averted was £15.06 (€17.66 US\$18.73) (bootstrap estimate 95%CI £11.04 to £36.22), similar to the estimate in the main analysis.

The estimated costs of the PCA equipment represent a substantial proportion of the additional costs associated with PCA, and more than half of the marginal costs in the abdominal pain trial. The cost assumptions used in the main analysis are that the equipment is purchased, with servicing and maintenance provided in-house. It has not been possible to find a cheaper leasing contract but comparisons are complicated because leading suppliers offer leasing arrangements supported by a wide range of accessories, training and maintenance service agreements. If equipment costs were to be completely excluded from the analysis (Scalley et al., for example, regarded them as sunk costs [12]), it would reduce the marginal cost by £3.49 (€4.09 US\$4.34) and the incremental cost effectiveness ratio by £4.65 (€5.45 US\$5.78) for the traumatic pain trial, and £2.62 (€3.07 US\$3.26) for the abdominal pain trial. The costs of staff time were based on the times per patient measured in the observational study. Both PCA and standard care pain relief have best practice schedules of observations and pain assessment, which were not always followed during the observational study. With the activity costs from the observational study it is possible to estimate the staff costs as they would be if the protocols were strictly observed. This results in an increase in the estimate of staff costs in both trials for both treatment groups. In the traumatic pain trial average staff costs would increase by £1.54 (€1.81 US\$1.91) in the PCA group and £4.43 (€5.20 US\$5.51) in the standard care group, resulting in an estimate of the incremental cost-effectiveness ratio of £22.91 (€26.87 US\$28.49) (bootstrap 95%CI £7.54 to £87.97). In the abdominal pain group staff costs would increase by £3.48 (€4.08 US\$4.33) in the PCA group and £1.83 (€2.15 US\$2.28) in the standard care group, with

an estimated incremental cost effectiveness ratio of £15.89 (€18.63 US\$19.76) (bootstrap 95%CI £8.71 to £51.23).

Discussion

Patient-controlled analgesia has been shown to be safe and effective in a variety of settings including postoperative pain management, burns and painful medical conditions [5, 13, 14]. Patient satisfaction with analgesia is correlated with involvement in pain management, no requirement for further analgesia, and the amount of pain relief received [15]. As PCA provides these conditions, it is usually popular with patients. Analgesia for patients managed in the emergency department is usually provided by nurse-delivered intermittent boluses of i.v. morphine. This practice is safe and effective in the short term, but places significant demands on nursing time, particularly when repeated doses are needed [16]. Despite this well-established approach, pain is often not treated effectively in the emergency department setting [17].

In common with previous economic evaluations of PCA technology in other settings, this evaluation found that the use of PCA for patients presenting to emergency departments with traumatic or abdominal pain reduced the amount of time they experienced moderate or severe pain, at an additional cost.

Health economic studies of acute pain are uncommon. Recently, however, a study of the impact of acute postoperative pain has revealed significant reductions in health-related quality of life using tools such as the EQ5D [18]. In this study, the cost-effectiveness of PCA was reported as the additional cost per hour in moderate to severe pain averted rather than in terms of quality-adjusted life years (QALY). In part, this reflects the aims and design of the two PASTIES clinical trials. Both trials included patients with a wide range of conditions with different associated patterns in quality of life and costs over time. The assessment of these diverse patterns was beyond the scope of the PASTIES trial, which focussed on the alleviation of pain during the relatively brief 12-h period following recruitment. More speculatively, it is not clear that acute pain in an emergency department setting would meet the QALY assumption of constant proportional trade-off; it seems likely that the inutility of an episode of acute pain is not constant with respect to its duration.

The comparatively short intervention period for the PASTIES study meant that the cost and benefits of PCA use, relative to standard care, were not assessed beyond the first 12 h. Longer term effects and costs of PCA use can be expected to be condition-specific and beyond the scope of this study. Chronic pain is common, affecting 20% of the general population in Europe and 18% of postoperative patients [19, 20]. The costs of chronic pain to the health service is significant; for example, 20% of the total health expenditure in the UK is used to treat chronic back pain [21]. It is known that acute pain correlates strongly with chronic pain at 6 months, and it is possible that PCA use may be associated with a reduction in chronic pain [22]. However, in emergency departments, decisions about pain relief are, as a rule, clinically exigent and can be reliably informed by immediate marginal costs and effectiveness of the alternative approaches.

Although this study demonstrated an increased drug cost for PCA, previous findings are equivocal. In comparison with conventional pain management, some studies have reported higher drug costs associated with PCA use [12, 23, 24] while others found that drug costs were lower [25–27]. Findings related to staff costs are more consistent, with PCA use being associated with lower costs [25, 28, 29]. Differences in the detailed findings possibly come about because individual studies have looked at the cost-effectiveness of postoperative PCA use following a range of procedures, in a variety of different healthcare systems and using an assortment of approaches to costing. Once PCA equipment costs are taken into account, however, almost all of the studies agree that PCA provides more effective pain relief at higher cost.

There are potential weaknesses of this study, two of which, the management of time asleep and the cost of PCA devices, are discussed above. Additionally, bias may have been introduced in the sampling process for the observational study, as patient selection was opportunistic, rather than randomised. Pain score data were drawn from participants at all sites enrolled in the PASTIES multicentre trial, whereas the observational study was based at the primary site only. Although the PCA devices were leased by some centres and purchased by others, there were very similar clinical protocols for PCA use, and it is unlikely that this will impact on clinical effectiveness. It would, therefore, seem reasonable to include all sites when calculating the incremental cost-effectiveness ratio.

This study presents the first evaluation of the incremental cost-effectiveness of the use of PCA in the emergency setting, following patients onto a hospital ward after admission from emergency department. The evaluation of the additional costs and pain relief associated with PCA in this setting provides useful additional information for clinical and service decision-makers regarding the incorporation of PCA in the management of patients presenting to an emergency department in pain.

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Appendix

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